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Investigation of Optical Properties of Fiber Bragg Grating (FBG)

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ABSTRACT

The world is constantly evolving in all aspects of life, the fastest development we can observe is in terms of communication, from sending letters to long-distance communication. The contribution of optics as one of the branches of physics is fairly global because indirectly, optics provides flexibility for users of breakthroughs in all corners of the world to use its services, namely telecommunications, namely in the use of electronic devices audio and video services. Optics itself is a part of physics that describes the behavior and properties of light which plays a very important role in communication technology. This FBG became a high-performance optical device that appeared as dispersion compensation in its transmission system. Bragg lattice fibers are optical fibers whose refractive index varies over time. In this optical task we analyze the Bragg fiber network (FBG) in terms of transmission waves as well as reflections, since changes occur when one of the parameters is affected.

Keywords: *Fiber Bragg Grating, Transmission Wave, Reflection, Transmittivity, Reflectivity*

1 Introduction

As time goes by, the world as we know it will undergo continuous changes, development will enter all aspects. Over time there will be many new breakthroughs created when their nature increases the effectiveness of life. For example, in ancient times, people only exchanged news and communication by sending letters that took days. With the new breakthrough, people can communicate over long distances quickly using telephones, which are supported by the transmission medium, namely optical fiber (Siburian, 2012). Through the branch of physics, it can be said that optical media bring changes that transfer old systems to new systems, in addition to communication is also promising as sensor applications in the future.(Juraszek & Antonik-Popiołek, 2021).

In the modern era, the guidance to communicate is said to be quite rapid, in ancient times maybe communication systems only provide voice services, far from that, nowadays the system has offered services in the form of a combination of audio and visual in communicating. This is due to the transmission wave as a communication signal transmitter wave which is also influenced by *Optical Add Drop Multiplexer* in increasing and also decreasing the wavelength on the transmission line (Sari, 2015).

During the renewal of the telecommunications system era, possible cases can be overcome by *Fiber Bragg Grating* It's like online remote distributed sensing, monitoring in security and Defense. This is due to the beneficial features of Fiber optic sensors such as selectivity and high sensitivity (Gao et al., 2022)(Zheng et al., 2016). Inside the optical Fiber there is a Bragg grid which as a transmission medium function as an optical filter. In the Bragg grid there are segments distributed separately with regular distances, which in this grid apply the principle of perfect reflection. Because in this lattice, later the light beam that comes on the casing will experience internal reflection and then be combined in the fiber without going through refraction.(Siahaan, 2015).

Please note, that FBG is a type of *Tributed Bragg Reflector* The wave that plays a role, the transmission wave is passed on at a specific wavelength, while a different wavelength will be reflected. To reflect these waves, FBG has periodic variations in the refractive index. The waves that play a role can be measured and analyzed for their characteristics.

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Utilization of transmission wave characteristics on *Bragg Fiber* It can be as a filter, which is a barrier or as a reflector of certain wavelengths of light. FBG characteristics include photosensitivity, apodization, dispersion, temperature, heat compensation, and other capabilities that are reliable in optical communication and in optical sensors. (Siahaan, 2015)(Fausta, 2013)(Hasudungan, 2022)(Hidayah, 2022).

Broadly speaking, the reflection that occurs in FBG is caused by periodic variations in the refractive index of optical fibers distributed in the form of a reflection spectrum lattice which in this case also complements each other with the transmission spectrum. In FBG, it is common to experience situations where there is no appropriate light to reflect, this may be triggered by one or more things. The reflection that occurs in fbg can be used as an optical application (Nai-Hsiang Sun et al., 2013). Therefore, this task will analyze how the transmission wave on fiber bragg grating occurs and how it is reflected.

2 Research Methodology

2.1 Theorical Foundation

Fiber bragg grating (FBG) the main media of telecommunications and communication technology whose way of working is based on physical concepts *Snellius*. The reflection will be produced by light as it passes through a low angle through the glass fibers(Surendro et al., 2015). *Fiber Bragg Grating (FBG)* is a type of filter whose refractive index changes periodically, allowing FBG to act as a reflector and transmitter. This change will later become a reflection on FBG (Murianti, 2018). FBG optical devices are capable of reflecting wavelengths of a certain nature, this depends on the grating period in the fiber core. (Widasari, 2013).

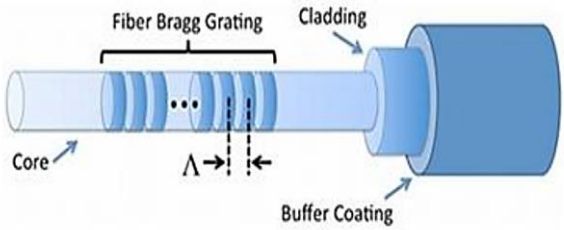

Figure 1. FBG on Fiber Optic

FBG technology is a popular choice for fiber optic sensors, especially for strain measurement or temperature measurement. This is due to the advantages possessed by *Fiber Bragg Grating* this in itself. In addition to its simple manufacture, relatively strong reflected signals, and the fact that wavelengths, its measurement parameters, are absolute in the universe, this is what underlies the change in conventional device techniques. (Werneck, 2017). Bragg wavelength (lamda) with grating period and mean refractive index (neff) is obtained by the equation

$$\lambda_{bragg} = 2n_{eff} \cdot \Lambda \quad (1)$$

Of course, to be able to stimulate sound rather than waves, vibrations, vibrations are measured using optical fibers that were previously developed by several researchers such as Zulaichah in 2004, he utilizes optical fibers *step-index multimode* which converts the displacement magnitude into voltage.(Putri, 2017). FBG is also based on bragg reflection, so when light propagates through alternating high and low refractive index regions, some of what is reflected (light) is reflected at each interface of that area. Reflection itself can also be interpreted as the number of wavelength integrals (Nasrulloh et al., 2021)

The time of reflection delay depends on its wavelength, its own duration

$$\tau(\lambda) = \frac{\lambda - \lambda_s}{(\lambda_L - \lambda_s}\frac{2n_{eff}L_g}{C}\ \lambda_s \leq \lambda \leq \lambda_L \quad (2)$$

Where Lg is the length of the lattice and c the speed of light, then to calculate the reflectivity achieved by FBG on each lattice fiber

$$Ri(\lambda) = \frac{sinh^2(L_g\sqrt{k^2-\sigma_i{}^2})}{\cos h^2(L_g\sqrt{k^2-\sigma_i{}^2})} \frac{1}{-\frac{\sigma_i{}^2}{k^2}} \text{ (Ali, 2023)} \quad (3)$$

2.2 Research Method

Measurement of the propagation properties of transmission waves passing through the Bragg lattice requires quite expensive costs, some of which are carried out using analytical methods and computer simulations. The most commonly used method is the theory of paired modes.

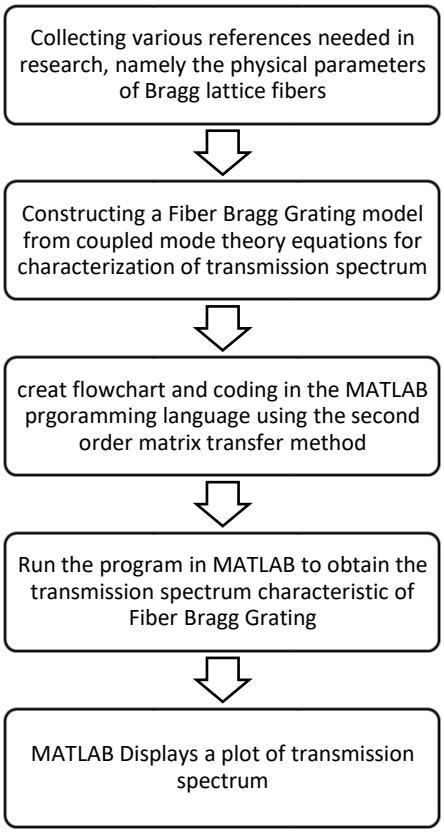

Figure 2. Research Flow Chart with Paired Mode

3 Results and Discussion

It is known through research and simulations that have been carried out before, related to the transmission characteristics of optical fibers, namely: experiencing light propagation; *Numerical aperture*; and as a wave guide (Paramarta, 2017) . The results showed that the transmission spectrum characteristics for one lattice varied with different reflectance values (Pramuliawati, 2015)

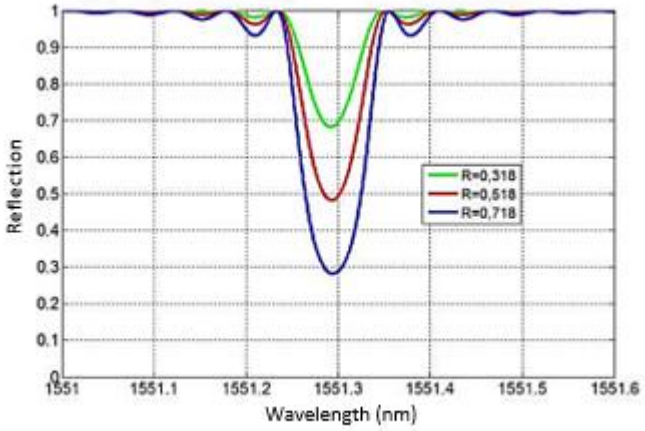

Figure 3. Transmission Spectrum of Different Grid Length Variations

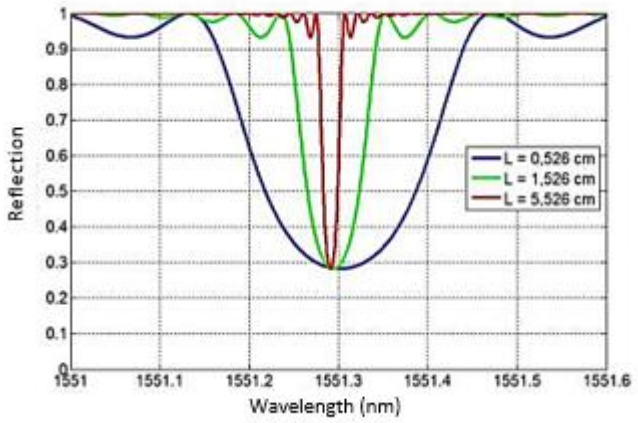

Figure 4. Transmission Spectra with Different Reflectivity Values

From the results of simulation and analysis of transmission and reflection work influenced by several parameters: (Ali, 2023).

Table 1. FBG Control Parameters

Parameters	Value
Λ	490 nm, 493.6 nm
n1, n2	1.4496,1.7
Ne	1.57
dne	1e-4
K	1e-5
N	1000
FBG length	0.49 mm, 0.493 mm

The table shows the control parameters during simulation and analysis, so the results obtained are as follows :

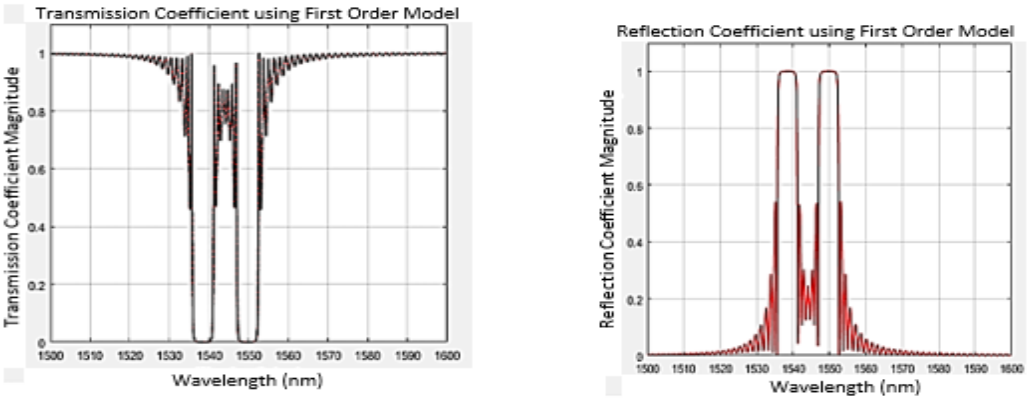

Figure 5. The Transmission Coefficient uses the first order model and the reflection coefficient uses the first order model

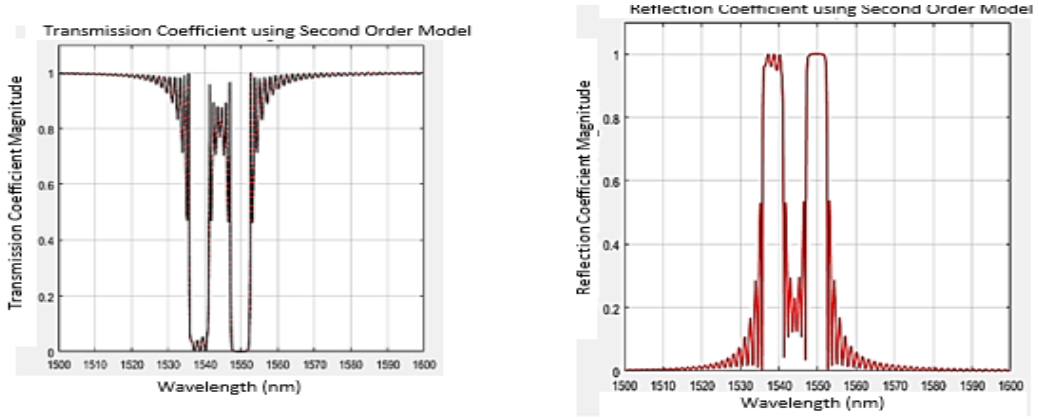

Figure 6. Transmission coefficient using the second order model and reflection coefficient using the second order model

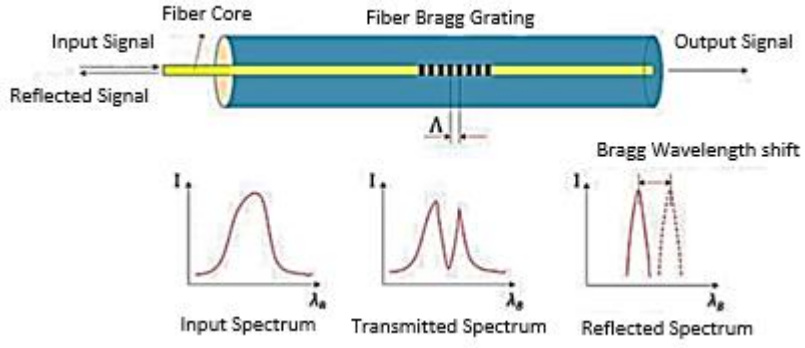

Figure 7. Fiber Bragg Grating (FBG) Sensor Diagram

Through analysis of the research that has been done, sensors from commercially available coated FBG are used to allow washing machines to have the use of monitoring loads at the beginning of bolt joints. The length of the Bragg lattice is 10 mm, the outer diameter of the fiber is 250 μm, and the core diameter of the optical fiber is 9 μm. (Chen, 2018). This research uses a bending system or commonly called the FBG Bending fiber optic indentation system. Flexible fiber optic cable can be loaded as much as 10 kg. the emphasis is indirectly applied to the FBG optical fiber, but is related to the sample surface. As a result,

the optical fiber bends and the emitted light is reduced. The decrease in light transmission affects the increase in light attenuation of optical fibers. Also, the attenuation can cause changes in the wavelength of light in FBG.

The research used something that harnesses changes in the wavelength of light for Bragg's fiber grating sensor system. The pressure exerted by the equilibrium weight causes a shift in wavelength. Through this study with a load of 10 kg. The load is tested on a certain sized rubber material. The working principle of the loading of the test material is that the rubber sample is placed on the balance so that the sample is bent. Bending of rubber samples can cause bending of optical fibers.(Hidayah, 2022).

Below is a graphical representation of FBG transmission in optimization software using the specifications shown in Table 2. A reflectivity of 99% was used in this study (Murianti, 2018).

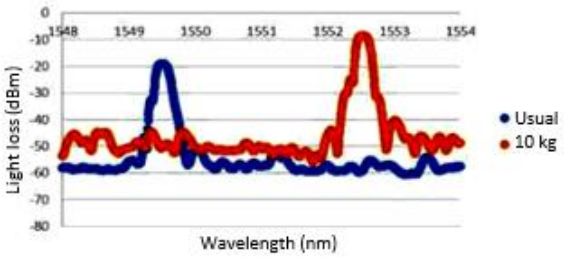

Figure 8. Graph of the relationship between wavelength and light loss before and after loading

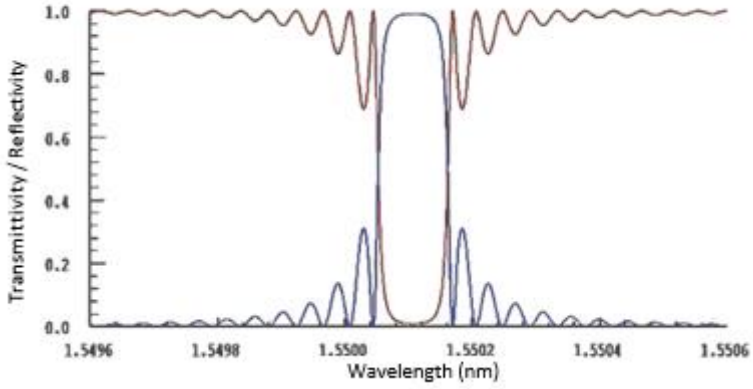

Figure 9. FBG transmitivy and reflectivity charts

4 Conclusion

With its characteristics, FBG can act as an optical reflector that reflects the required wavelengths and emits other wavelengths. Conditions with high reflectivity are called Bragg conditions. The wavelength produced by fbg is influenced by parameters such as the value of attenuation, macrobend loss, dispersion, Λ, gain, damping, cladding and coating diameter, MFD, and channel spacing. That from the analysis of several experiments that have been carried out the best scheme is Pre-compensating and with FBG Optisystem simulation which produces stable values. The influence of high temperature will make the wavelength smaller, in the sense that temperature also affects the length of transmittivity.

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